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Intense upper anticyclonic spirals in the process of sudden and rapid small and meso scale accentuations

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सार – निम्नतल प्रणाली के द्रुत प्रचण्डीकरण के लिये पूर्ववर्ती निम्न अभिसरण पर उच्च अपसरण का अध्यारोपण एक सुविदित तथ्य है। भारतीय ग्रीष्म कालीन मानसून क्षेत्र में कुछ लघु या मैसो-मापी प्रणालियों लघु क्रोड़ित उच्च प्रतिचक्रवाती स्पाइरलों के दिखाई देने से जुड़ी हैं। इन प्रणालियों का द्रुत तथा तीव्र विकास निम्न स्तरीय प्रणालियों पर कैसे आंशिक रूप से आरोपित होता है। परिणाम स्वरूप ये विकास इस प्रकार के विशिष्ट मैसो या लघु मापी विशिष्टीकरणों के लिये किस प्रकार अग्रधावी बन जाते हैं। यह दिखाने का एक प्रयास यहाँ किया गया है।

ABSTRACT. Superimposition of upper divergence on pre-existing lower convergence is a well known fact for rapid intensification of the low level system. An attempt is made to show how rapid and intense developments of some of the small or meso scale systems in the Indian summer monsoon field are actually associated with the appearance of small cored upper anticyclonic spirals fractionally imposed on the low level systems, the upper anticyclonic spiral, thereby, serving as a forerunner for such typical meso or small scale accentuations.

1. Introduction

1.1. In this paper some typical cases of accentuations of meso and small extent are discussed, where, rapid intensification took place in pre-existing low level convergence of the Indian summer monsoon field.

1.2. The cases discussed are :

(1) *The Raigarh-Champa-Sambalpur area of* 24/25 *August* 1970 — Raigarh reporting exceptionally heavy fall of 33 cm and Sambalpur and Champa very heavy falls of 15 and 13 cm respectively on the morning of 25th.

(2) *The Akola area of* 24/25 *September* 1970 — Agola Airport reporting exceedingly heavy fall of 21 cm and, the city, very heavy fall of 15 cm on the morning of 25th.

(3) *The Ramagundam-Sironcha area of* 25 *September* 1979 — Ramagundam and Sironcha recording 11 and 10 cm on the morning of 26th.

(4) *The Yeotmal area of* 20/21 *September* 1981— Yeotmal recording an exceedingly heavy fall of 22 cm on the morning of 21st.

(5) *The Malegaon-Jalgaon-Ahuwa area of* 19/20 *June* 1982 — Malegaon, Jalgaon and Ahuwa (Gujarat) recording exceedingly heavy falls of 24, 19 and 19 cm respectively on the morning of 20th.

1.3. The synoptic situation at the lower troposphere in all the cases — the appearance of small cored intense embedded in the monsoon field. The situation in the upper troposphere had been, categorically, the same in all the cases — the appearance of small cored intense anticyclonic spiral, fractionally imposed on the lower convergence.

1.4 The resultant accentuation was, however, in the form of rapid and exceedingly heavy downpour in small area — the neighbouring places reporting a little or no rainfall at all. The natural calamity in the localized areas was high. In the case of Raigarh-Champa-Sambalpur area, the town of Raigarh was under water. In the case of the Akola area, flash floods in the small river *Murna* brought in severe devastation with loss of life. In the case of Ramagundam-Sironcha area and the Yeotmal area, sudden inundation brought in extreme suffering for the people. In the case of the Malegaon-Jalgaon-Ahuwa area, in Jalgaon and Malegaon towns there was heavy damage and loss of life as reported by the press.

2. Chronological study

2.1. *Raigarh-Champa-Sambalpur area between* 24 *and* 25 *August* 1970

2.1.1. On 24th (0000 GMT), the monsoon trough extended from northwest India to Orissa coast with

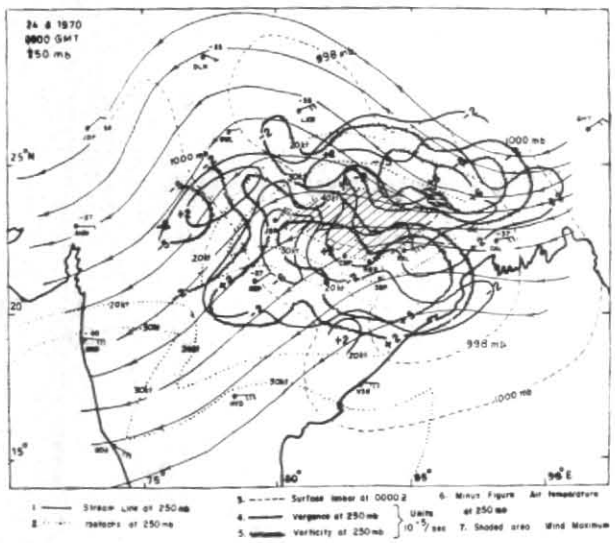


Fig. 1

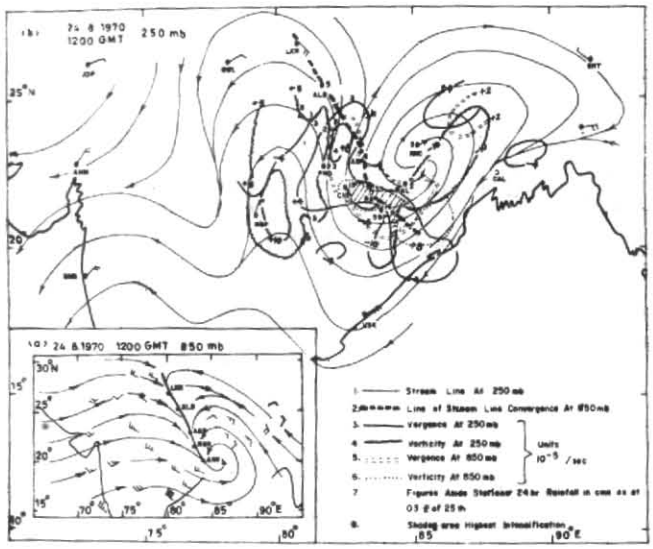


Fig. 2(a & b)

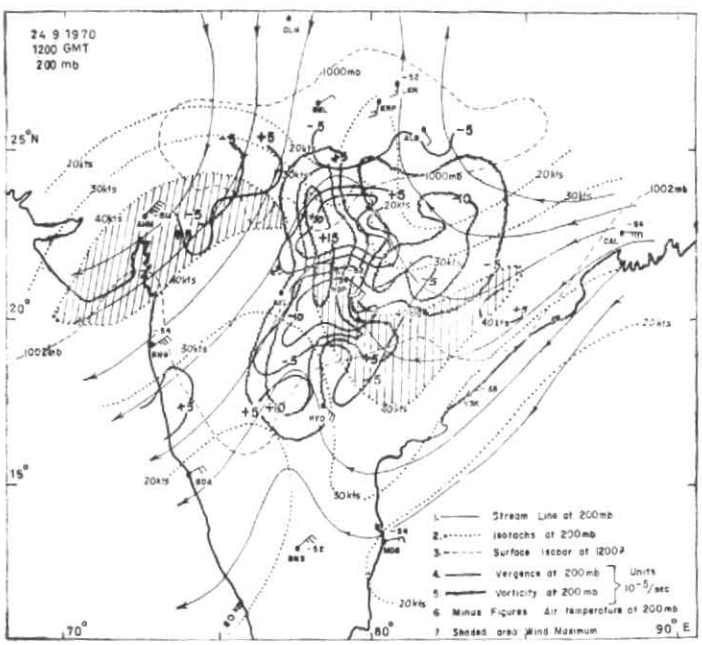
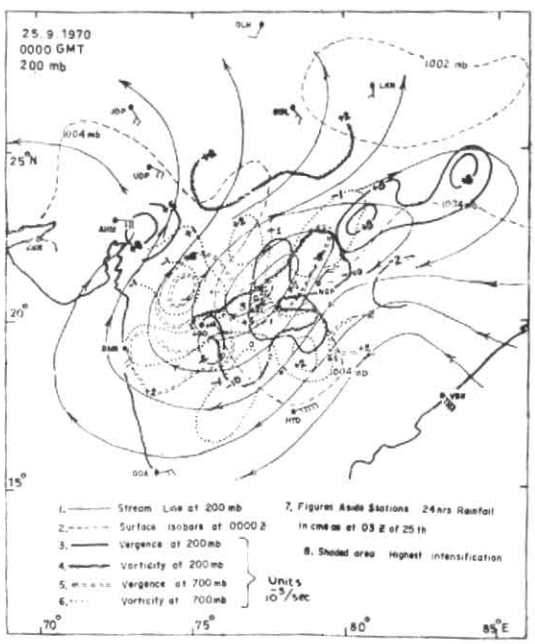


Fig. 3



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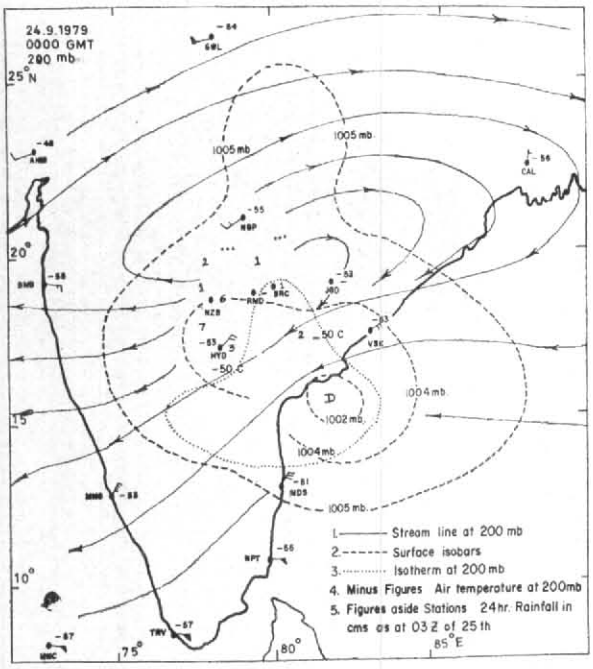

Fig. 5

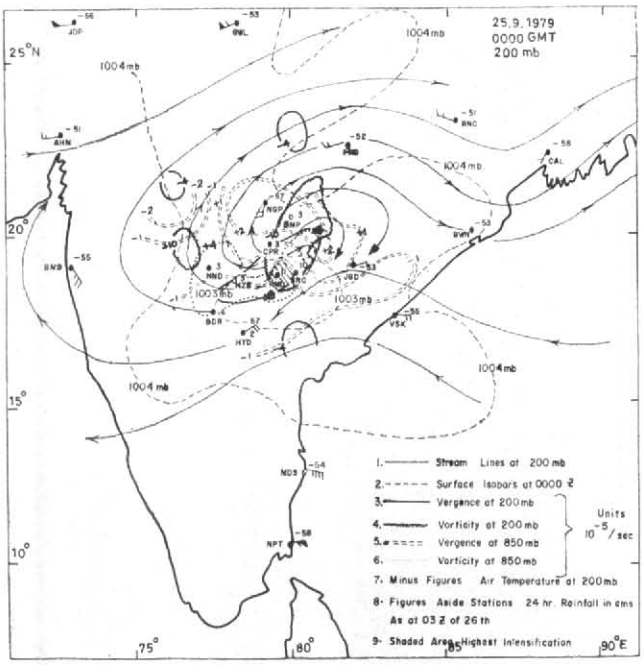

Fig. 6

an embedded low pressure area over northeast Madhya Pradesh and the adjoining area of Uttar Pradesh and Orissa (Fig. 1). In the upper troposphere, at the representative level of 250 mb, a diffluent stream of easterlies was exhibiting cyclonic curvature while responding to an amplification from east Madhya Pradesh to northwest Madhya Pradesh. The convergent sector of the amplified easterly trough was possessed by appreciable speed divergence*—isotachs showing wind maxima over the central parts of east Madhya Pradesh, containing the Raigarh-Champa-Sambalpur area (Fig. 1). In the evening 1200 GMT, the low level convergence, at the representative level of 1.5 km a. s. l., was well obsereved as a meridional line of streamline convergence, passing through Lucknow, Allahabad, Ambikapur, Raigarh and Angul — allowing monsoon easterlies and westerlies converge with the drier northwesterlies (Fig. 2a). In the upper troposphere, at the representative level of 250 mb, a small cored anticyclonic spiral formed with centre close to Rourkela (Fig. 2b). Heavy rains followed in a small area of Raigarh-Champa-Sambalpur only — Raigarh reporting 33 cm and Sambalpur and Champa 15 and 13 cm respectively on the morning of 25th (Fig. 2b). By 25th morning, the lower tropospheric line of streamline convergence shifted west and the upper anticyclonic spiral became non-existent. Rainfall activity also declined abruptly.

2.2. *Akola area from* 24 *to* 25 *September* 1970

2.2.1. On 24th morning and evening, in the lower troposphere, there was a well marked eddy trough embedded in the monsoon trough, running north-south across the Akola area (Fig. 3). In the upper troposphere, a diffluent stream of easterlies was undergoing amplification from Telangana to north Madhya Pradesh with a considerable speed divergence in the convergent sector. At the representative level of 200 mb, at 1200 GMT, the isotachs were showing wind maxima slightly east of the Akola area (Fig. 3). By the morning, 0000 GMT of 25th at the representative level of 200 mb, and anticyclonic spiral of small core formed, centred near Akola, with the surface eddy trough still there (Fig. 4). In between, at 2100 GMT of 24th, a meso low also formed around the Akola area, weakening by the morning. Heavy downpour started in a meso area around Akola from 2100 GMT of 24th, Akola Airport reporting 21 cm against 13 cm for the city on the morning of 25th (Fig. 4). The autographic charts revealed that out of the total of 21 cm for the Akola Airport, 19 cm fell in course of a short span of 6 hours between 2100 GMT and 0300 GMT, signifying an intense precipitation. By 25th evening, the eddy trough and the upper anticyclonic spiral dissipated and then rainfall activity in the area ended.

2.3. *Ramagundam-Sironcha area between* 24 *and* 25 *September* 1979

2.3.1. On 24th, 0000 GMT, a depression was crossing the Andhra coasts associated trough extending to Uttar Pradesh area (Fig. 5). In the upper troposphere, at the representative level of 200 mb, there was a separation of the upper easterlies and the westerlies along 19 deg. N, wherein, appeared a small pool of warmer air, engulfing the Ramagundam-Sironcha area (Fig. 5). The depression, after crossing the coasts weakened and at 0000 GMT of 25th, it was lying as a low over southeast Madhya Pradesh and the adjoining south Vidarbha (Fig. 6). In the upper troposphere, at the representative level of 200 mb, an

*The upper winds of Rourkela and Jabalpur are taken from the AIREP data plotted in the charts of the Meteorological office, Colaba, Bombay.

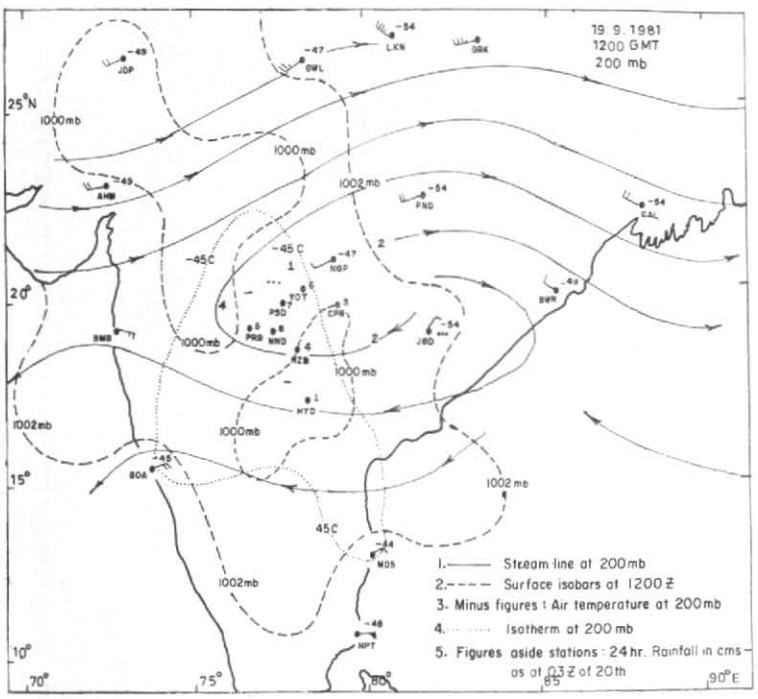

Fig. 7

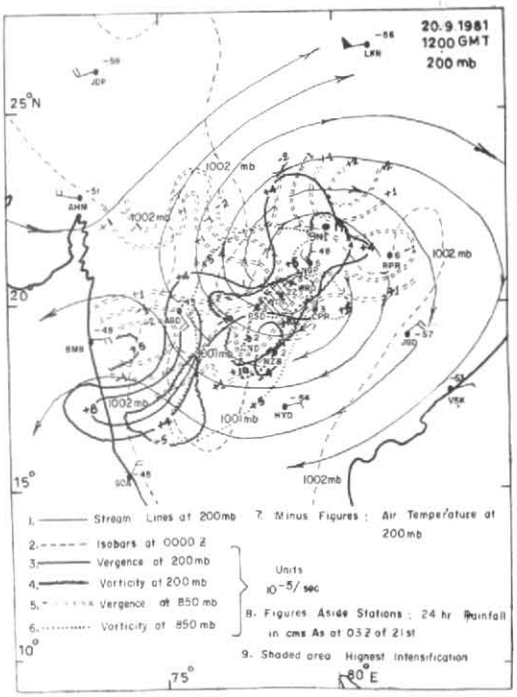

Fig. 8

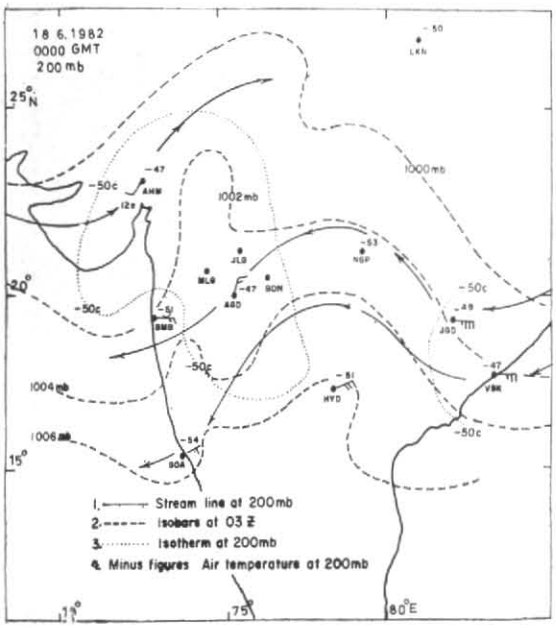

Fig. 9

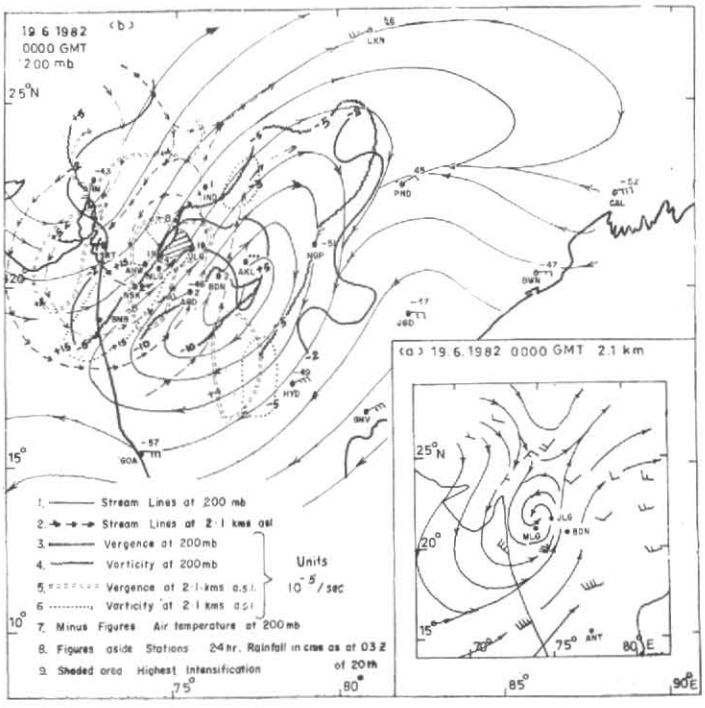

Fig. 10 (a & b)

anticyclonic spiral of small core formed, centred between Brahmapuri and Sironcha, still containing the warm pool of air around (Fig. 6). By 0900 GMT, the low became well marked around the Ramagundam-Sironcha area. Rapid downpour started in the small Ramagundam-Sironcha area, lasting only from 0900 GMT to 1200 GMT of the day. Within the course of 3 hours, Ramagundam and Sironcha recorded heavy falls of 11 and 10 cm respectively and a little rainfall in the neighbourhood (Fig. 6). By 1200 GMT, both the well marked low and the upper anticyclonic spiral became non-existent and the heavy rains abated.

2.4. *Yeotmal area between* 18 *and* 20 *September* 1981

2.4.1. On the 18th, a depression was just crossing the Andhra coasts, associated monsoon trough extending northwestwards to south Rajasthan. The depression, after crossing the coasts, weakened and by 1200 GMT of 19th, was lying as a well marked low over Telengana, just skirting the south Vidarbha area (Fig. 7). In the upper troposphere, at the representative level of 200 mb, there was a separation of the easterlies and the westerlies, the ridge line passing approximately along 20 deg. N, with a small pool of warmer air into it, engulfing the Yeotmal area (Fig. 7). By 1200 GMT of 20th, the well marked low became a feeble low over Marathwada and adjoining south Vidarbha, containing the Yeotmal area (Fig. 8). In the upper troposphere, at the representative level of 200 mb, an intense small cored anticyclonic spiral formed, centred near Wardha, with the small warm pool of air still around it (Fig. 8). A meso low formed around the Yeotmal area at 1800 GMT. Along with rainfall in Vidarbha and the areas south of it, spectacularly, heavy fall occurred over a meso area of Yeotmal; Yeotmal recording 22 cm next day morning (Fig. 8). The autographic charts of Yeotmal revealed that out of the total of 22 cm, 21 cm fell in course of 2230 GMT of 20th and 0230 GMT of 21st, signifying a very high rate of precipitation. On 21st, the low moved north and the upper anticyclonic spiral became non-existent. Heavy rains abated, but, for a reminiscence of 8 cm for Amraoti.

2.5. *Malegaon-Jalgaon-Ahuwa area between* 18 *&* 19 *June* 1982

2.5.1. On 18th morning, in the monsoon field, a well marked trough extended southwards across the south Gujarat coasts (Fig. 9), the associated cyclonic circulation extending to the mid-troposphere. In the upper troposphere, at the representative level of 200 mb, ridge line seperating the upper easterlies and the westerlies passed approximately along 22 deg. N, with a small pool of warmer air into it, engulfing the west Vidarbha area (Fig. 9). By 19th (0000 GMT), at the representative level of 2.1 km a. s. l., the cyclonic circulation was over Madhya Maharashtra and adjoining Gujarat, centred near Jalgaon [Fig. 10 (a)]. In the upper troposphere, at the representative level of 200 mb, a distinct small cored anticyclonic spiral formed, centred close to Buldana (Fig. 10b). By 0900 GMT, a meso low formed around the Jalgaon area. Exceedingly heavy rains followed in the small Malegaon-Jalgaon-Ahuwa area, Malegaon, Jalgaon and Ahuwa recording 24, 19 and 19 cm respectively on the next day morning, against far less amounts in the neighbourhood (Fig. 10b). On 21st, with the cyclonic circulation persisting over south Gujarat, the upper anticyclonic spiral became non-existent. Rainfall activity in the area decreased abruptly, except for a reminiscence of heavy fall over Ahuwa.

3. Discussion

3.1. *Type of accentuation and its identification* — Isolated heavy rains do occur in the monsoon field, associated with depressions, cyclonic storms, orography, etc. But, in the absence of any of the major systems or orography, to account such rapid and exceedingly heavy rains, confined in only a small area, it requires detailed study. The participants in the lower troposphere, were the convergences in the form of : (1) meridional line of streamline convergence for the Raigarh-Champa-Sambalpur area (Fig. 2a), (2) well marked surface eddy trough for the Akola area (Fig. 3), (3) embedded lows in the monsoon trough for the Ramagundam-Sironcha area (Fig. 6) and the Yeotmal area (Fig. 8) and (4) cyclonic vortex for the Malegaon-Jalgaon-Ahuwa area (Fig. 10a). In the upper troposphere, typically, for all these five cases, there was a common feature, the small cored anticyclonic spiral (Figs. 2b, 4, 6, 8 and 10b). In all the cases, this upper anticyclonic spiral was seen to be fractionally imposed on the lower convergence. Intense development in a meso/small area, corresponding to the superimposition, was triggered off, only after the appearance of this upper anticyclonic spiral. The upper anticyclonic spiral, therefore, serves as a forerunner and its recognition with reference to the lower convergence becomes a tool for the identification of such typical accentuations, the process of development, obviously, being the favourable superimposition of lower convergence by upper divergence.

3.2. *The formation of upper anticyclonic spiral and its role in the development*

3.2.1. *Formation* — A careful qualitative survey of the cases shows that the anticyclonic spirals are formed under two distinct processes in the upper troposphere : (1) in a diffluent easterly stream undergoing amplification and the convergent sector possessed by wind maxima amounting to high anticyclonic shear (Figs. 1 and 3), being a shear type and (2) in that part of the ridge line separating the upper easterlies and the westerlies, where a small pool of warmer air is advected (Figs. 5, 7 and 9), being a warm pool

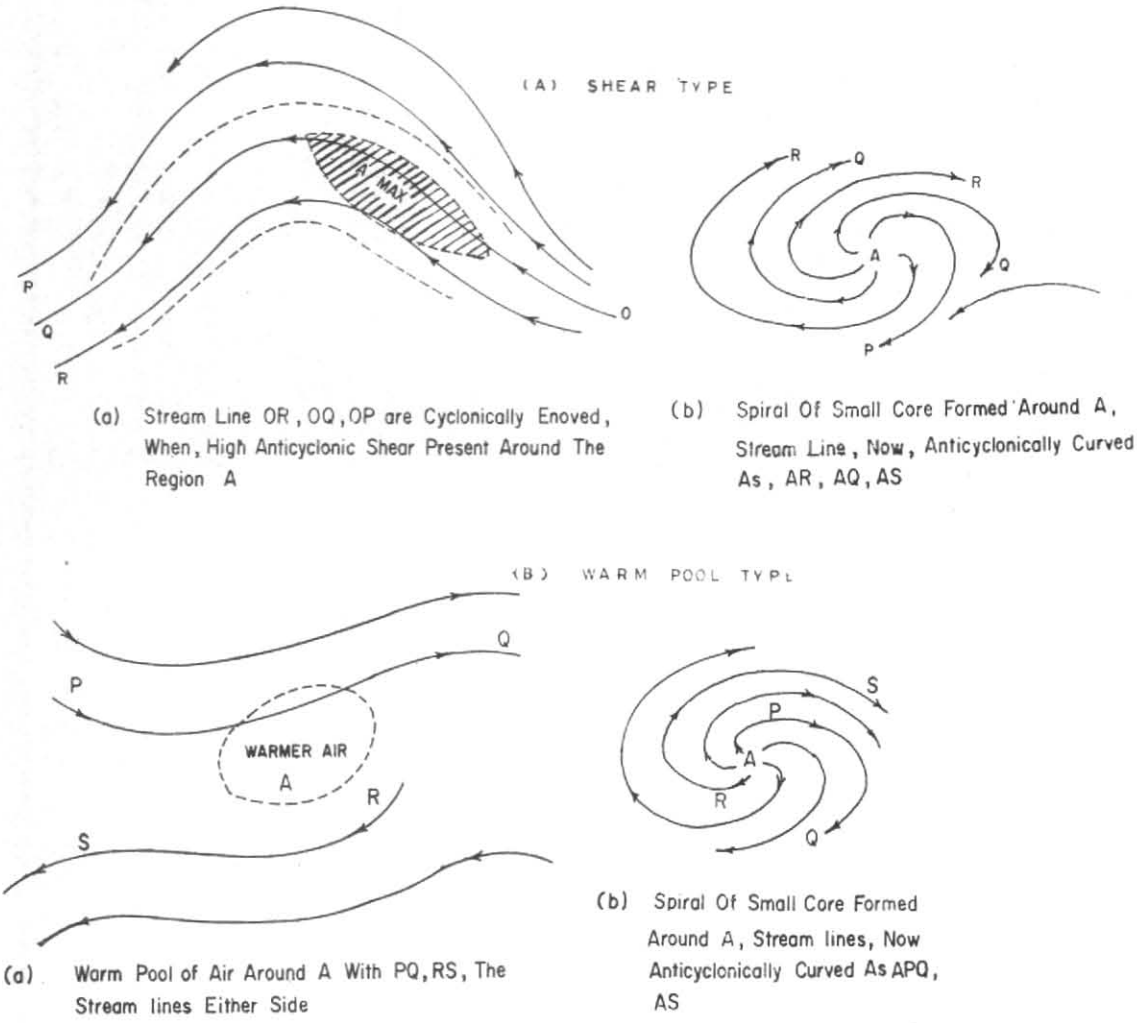

Fig. 11

type in the case of the shear type, the convergent sector is subject to cyclonic curvature and high anticyclonic shear. This, as has been pointed out by Reihl (1954), poses a complexity in the nett assumption. The contribution from the shear term far excelling the curvature term, the net vorticity assumption is, in favour of anticyclonic. This result can be seen in Figs. 2(b) and 4, where finally anticyclonic spirals formed. The contention has also been substantiated quantitatively in the following discourses. In the case of the warm pool type, already, a separation between upper easterlies and the westerlies exists and with the advection of a small pool of warmer air into it, under the conceptual effect of thermal wind (Hess 1959), turning of the winds towards anticyclonic spiral formation, keeping the warmer air to the right, is favoured (Figs. 6, 8 and 10b). To explain the source of the warm air, the reason has to be sought elsewhere in the field, the present discussion limited to the factual observation of the warm pool only.

3.2.2. *Role in the development* — The upper anticyclonic spirals formed in all the cases are seen to be of small core and fairly high peripherial winds. An application of the equation of potential vorticity.

$$\xi = f + \frac{v}{r_s} - \frac{\partial v}{\partial n} / \Delta p = \text{constant},$$

would suggest an enormous decrease in the value of the numerator, because of : (*i*) high numerical value of the shear term $\partial v/\partial n$ around the small core; (*ii*) fairly high negative value for the curvature (anticyclonic) term v/r_s near the centre or the immediate periphery, under the limit $r=0$, $v=0$, (*iii*) negligible change in the coriolis parameter f for the small core. For constancy of the equation, the vergence term Δp in the denominator decreases enormously. This signifies high divergence for the upper anticyclonic spiral near the

centre or the immediate periphery. The core of the upper anticyclonic spiral being very small, the high divergence out of it can, therefore, be favourably imposed, only on a small part of the lower convergence. Moist air of the lower troposphere, appropriate to this favourable conjunction, is only subjected to the intense development.

4. Quantitative substantiation of the accentuation cases

4.1. *Object of the quantitative survey and the method used — The* formation of the upper anticyclonic spiral of the shear type, where,wind configurations are involved and the delineation of the exact meso or small areas of accentuation, where, fractional superimposition of lower convergence by upper divergence is concerned, it requires a quantitative substantiation for justifying the events. This is done by evaluating the vergence and vorticity at the representative levels. The method used, is that of Graham (1953), by arranging a set of equilateral triangles in the field, the unit for the evaluated values being 10^{-5}/sec. For delineating the area highest accentuation, an optimum conjunction of highest upper divergence *cum* anticyclonic vorticity with highest lower convergence *cum* cyclonic vorticity is tried on a map (Miller and Keshavamurthy 1968 and Ramage 1971) preference given to the highest deployable upper divergence that governs degree of the development (Petterssen 1956)

4.2. *Substantiation of the upper anticyclonic spiral of the shear type*—Evaluating the vergence and vorticity in the units of 10^{-5}/sec and reading positive and negative vergences as divergence and convergence respectively it is seen that in the case of the Raigarh-Champa-Sambalpur area, as at 0000 GMT (Fig. 1), the amplified part of the trough is composed of convergence —2 to—6 *cum* cyclonic vorticity+5. But, in the rest of the convergent sector, particularly in the region of the wind maxima a different combination exists. The down stream part of the wind maxima has the combination of cyclonic vorticity+2 to+5 with high divergence+2 to+6, whereas the upstream part is under dominance of high divergence+6 *cum* anticylonic vorticity—2 to—5. The result, by 1200 GMT, is a complete take over of the wind maxima area by an anticyclonic spiral with high divergence+4 *cum* anticyclonic vorticity—10, centred near Rourekela (Fig. 2). In the case of the Akola area, at 1200 GMT (Fig. 3), the entire convergent sector, with the wind maxima area to the east of Akola shows a varied combination. The high cyclonic vorticity of+10 to+15 in the amplified part of the trough and the wind maxima area to the down stream is largely dominated by a high divergence +5 to+10 to the northeast of Akola, leaving room for a share of convergence—5 to—10 to the southeast of Akola, when, same time, a high anticyclonic vorticity—5 to—10 awaits in the rest of the convergent sector upstream, including a part of the wind maxima area. The result, as seen at 0000 GMT of the next day, is an anticyclonic spiral with high divergence +5 *cum* anticyclonic vorticity—10 centred slightly northeast of Akola(Fig.4). This spiral formation can be thought of been formed earlier, timed with the start of the intense development that resulted into heavy downpour in the Akola area from 2100 GMT, absence of high ascents between 1200 and 0000 GMT apparently vitiating the prospects of sighting the spiral earlier.

4.3. *Substantiation of the exact meso/small areas of accentuation*

4.3.1. For favourable superimposition vergence and vorticity in the representative lower and upper levels are evaluated in the units of 10^{-5}/sec. The lower representative layers are : the 850 mb for the Raigarh-Champa-Sambalpur, the Ramagundam-Sironcha and the Yeotmal areas; the 700 mb for the Akola area and the 2.1 km level for the Malegaon-Jalgaon-Ahuwa area. The upper representative layers are the 250 mb for the Raigarh-Champa-Sambalpur area and the 200 mb for the rest of the areas.

4.3.2. Superimposing upper divergence *cum* anticylonic vorticity aloft lower covergence *cum* cyclonic vorticity in the units of 10^{-5}/sec, it can be seen that in the Raigarh-Champa-Sambalpur area (Fig. 2b), all the highest values but for the far off upper divergence of+8 are conjunctionable, delineating a small area with upper divergence *cum* anticyclonic vorticity of+4 *cum*—10 and lower convergence *cum* cyclonic vorticity of—4 *cum*+8. In the case of the Akola area (Fig. 4), except the highest upper anticyclonic vorticity, all other highest values are far from each other, allowing an optimum conjunction with upper divergence *cum* anticyclonic vorticity of +5 *cum*—10 and lower convergence *cum* cyclonic vorticity of—2 *cum* +1 as to delineate a meso area. In the case of the Ramagundam-Sironcha area (Fig. 6), except for the far off lower convergence—2, all other highest values are in conjunction as to delineate a small area with upper divergence *cum* anticyclonic vorticity of+8 and—10 and lower convergence *cum* cyclonic vorticity of—1 *cum*+4. In the case of the Yeotmal area (Fig. 8), the highest values of upper divergence +8 and lower convergence —2 being far off, the optimum conjunction is with upper divergence *cum* anticyclonic vorticity of+4 *cum*—10 and lower convergence *cum* cyclonic vorticity of—1 *cum*+10. In the case of the Malegaon-Jalgaon-Ahuwa area (Fig. 10b), with the highest upper divergence available, the optimum conjunction is with upper divergence *cum* anticyclonic vorticity of+5 *cum*—5 and lower convergence *cum* cyclonic vorticity of—8 *cum*+10 as to delineate a small area between Jalgaon and Malegaon-Ahuwa.

5. Model

The paramount feature in all these typical cases, that serves as the forerunner, is the upper anticyclonic spiral. A schematic model outlining assumption of this spiral is appropriate enough for the favourable conjunction that follows next. Supported by both the qualitative and

the quantitative discussions, a schematic model on the formation of both the shear type and the warm pool type upper anticyclonic spirals is shown in Fig. 11.

Acknowledgement

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